NASA-JPL-AUDIO-CORE
Moderator: Heather Doyle
February 20, 2018

Heather Doyle: Great. Thank you, operator. Today, we have a really interesting topic and a great speaker. First thing I'm going to do is welcome you and make sure that everybody knows the etiquette today which is you're muting yourselves. So, it is star six to mute. If we start to hear a little background noise, we'll just shout out a reminder to do that.

We'll take questions at the end unless Dr. Klesh, you don't mind them interrupting you throughout. But, we usually wait until the end to ask questions. And, I'll turn the time over the Sarah Marcotte who is the lead for Mars Education and Outreach here at JPL. So, Sarah, if you'd like to introduce the speaker, I'll turn it over to you.

Sarah Marcotte: Sounds great. Hi everyone. Sarah Marcotte here from Mars Public Engagement. Looking forward to our first interplanetary launch from California. The insight lander with MarCO CubeSats following the lander along to Mars. So, we have Dr. Andy Klesh today who is one of the leads on this first CubeSat going to Mars. So, we have a couple of firsts. First launch tomorrow is from California and first CubeSats going to Mars.

So. Loving it. He's the chief engineer for interplanetary small spacecraft here at NASA JPL and he is responsible for these first two CubeSats headed beyond Earth. He was the principal investigator for the INSPIRE interplanetary CubeSats. And, he was at University of Michigan's Radio Aurora Explorer CubeSat project. So, I think he's got some experience in CubeSats. So, serving as the technical lead of something that's totally different. The buoyant rover under ice exploration team.

Which is actually a rover that can roll underneath ice sheets. So, I've seen some of that work and it's fascinating. So, that project works to explore the ice water interface in the Arctic, Antarctic and glaciers. And, before coming to JPL, he was a post-doctoral fellow at JAXA, which is Japanese Space Agency supporting the Hayabusa and Ikaros missions.

And, he's spent a lot of time at the University of Michigan. Has multiple degrees. Including a, I don't know what all of these are. BSCEE. Looks like Bachelor of Science and Engineering. And Aerospace Electrical Engineering and engineering of space systems. So, Andy, you've got a lot going on. So, he will present his slides, and everyone follow along. And we will take questions at the end. Take it away, Andy.

Dr. Andy Klesh: Thank you Sarah. And thank you everyone for joining us today. The MarCO Mission a unique one as was indicated that these are the first CubeSats to head beyond low earth orbit. In fact, these CubeSats began back in 2003 as university endeavors to start to explore, what could students do if they had a readily available ride to orbit to test out technology.

To learn new things about space systems, and to try out new science opportunities. In more recent years, we've begun to ask, how could we used CubeSats beyond the Earth and to advance ourselves in planetary exploration and start to answer other questions on there. Most of these CubeSats are very small. 10 by 10 by 10 centimeters on the side. Only about a kilogram or so. Or, at most, three to five kilograms when we launch into lower Earth orbit. And yet, they have begun to provide fantastic opportunities.

Not only for the students, but for commercial endeavors such as planet labs out there. And others that are starting to image the Earth and return remarkable science. You know, all this data combined as come from a low Earth orbit altitude of only about 600 to 650 kilometers above the Earth. In the MarCO mission, we are going far, far beyond that. Approximately 158 million kilometers out to Mars. In today's presentation, I'd like to give you an overview of what we are doing with MarCO, or the Mars Cube One spacecraft.

How they are going to support the InSight mission along the way, and what you might see in the upcoming months. Now, originally, I understand that you have also heard about the InSight mission previously. You know that InSight was supposed to head to Mars back in 2016, but unfortunately experienced a delay. That meant, of course, that the MarCO spacecrafts carried along with InSight, would also be delayed.

So, now we are set to launch on May 5th, 2018. At the beginning of our launch window at the Vandenberg Air Force Base. On the second slide in the package, you can start to see what we will be experiencing on May 5th. With the Atlas 5 vehicle launching form Vandenberg headed out to Mars. Just after launch, approximately 90 minutes later, the inside vehicle will separate from that rocket and start its cruise phase.

That center picture that you see. As it heads over the Mars. And will travel this way for six and half months. On November 26th, 2018, InSight will go through entry, decent and landing. Coming down for a soft landing on the surface of Mars, ready to begin its geophysics mission. Now, entry, decent, and landing is a very interesting period of any Mars mission.

It's one of the more terrifying ones. In fact, we call it the seven minutes of terror. Because, so many space craft in the past have run into various issues. As might be expected if we were to start exploring another planet. It was during this part of the mission that the MarCO spacecraft come into play. Because, though we have orbiters around Mars itself, it turns out that they are not in the right geographic locations in order to relay data during InSight's, entry, decent and landing back to Earth.

That is, we may not know what happened directly with InSight until several hours later. At least, in detail. So, this particular mission, the Mars Recognizant Orbiter passing overhead will record all signals from InSight and store that for later transition to the ground. Meanwhile, on Earth, we will only receive basic UHF tones. Basic low-radio tones saying what phase of the mission InSight is in.

And this is when MarCO comes into play. Because, six and a half months after launch, when passing by Mars as InSight goes through entry, decent, and landing. MarCO will relay information from the InSight lander back to earth, providing Earth a real time look on how the InSight lander is doing on it's way down to land safely on Mars. MarCO itself is not critical for mission success. It is not required for any part of InSight mission success. But, it is a technology demonstration mission, showcasing how small spacecraft can serve a greater function with the larger primaries.

As well as showcasing how many smaller CubeSats can survive the onset orbit. On the next slide 3, you can see that there is, there are quite a few activities that actually have to occur with MarCO as it heads out to Mars. Just after separation, we have two spacecraft that are actually separating from the upper stage of the Atlas rocket. Now, these two spacecraft will independently fly their way to Mars.

Because of various requirements you have due to planetary protection, that is not to contaminate the surface of Mars from our main rocket, we actually will slowly have to steer ourselves two Mars with five trajectory correction motors, or TCMs. These TCMs are spaced over the six and a half month cruise. Aimed to provide just the right location for MarCO on that fateful day, when InSight is going in for entry, decent and landing. The following slide 4 shows a CAD image of the MarCO spacecraft itself.

It's one of our two space craft. And MarCO has a fundamental mission objective. Provide and eight kilowatt per second real time relay for InSights EDL at Mars. You can see a few interesting features for this particular CubeSat. Most notably, is the CubeSat itself is not a cube. While we start off with this rectangular prism when we are inside our dispenser. Over the course of the mission, we unfurl solar rays.

We deploy a large high gain antenna. And, we also deploy a UHF antenna pointed down towards the InSight lander. I'll go into more detail on each of these in a little while. But, overall, you can see the size of the spacecraft. It's not much more than a large Sam's Club Cereal Box. And we'll be sending two of these out towards Mars. The following slide 5 takes off the cover of MarCO and shows some of the items that were within the vehicle itself. Over on the left and right of the vehicle, you can see two solar arrays.

Each of these solar arrays, provided by a small company called MMA. And they provide about 35 watts of power near earth, and about 17 watts of power out near Mars. This is only half to a quarter of what a normal 60-watt light bulb might provide in terms of light at home. In between those two solar arrays is a bright blue box. That box is actually a propulsion system.

Cold gas thrusters provided by VACO. And the thrusters themselves actually use a fire extinguisher. That is what you would normally find in a Halon Replacement fire extinguisher, is what we are using to fly ourselves to Mars.

We are essentially Wall-E headed out into space and aiming ourselves at Mars along the way, steering as needed to pass by that very specific point. Directly below the propulsion unit, is the primary piece of our spacecraft. The X band transponder.

The primary radio that we need to communicate both with the InSight lander as well as with Earth's deep space network. Navigating and communicating data back and forth to get ourselves out to Mars. This is a special piece of technology that JPL has been developing over the last few years. And, unlike some of the previous spacecraft, this one is not much larger than the size of your fist.

It is quite a small radio for all of the capability that's been built in. Underneath this radio, we have the amplifiers needed to receive and transmit data to the spacecraft. As well as the high gain reflector array. In essence, this is a large parabolic disk, but with the magic of radio waves and electromagnetic theory, we've been able to make it into a flat plate. Able to be stowed and folded against the spacecraft for launch.

And then deployed, but yet still able to concentrate our beam, to give a very narrow beam back to Earth concentrating all the power that we can. Just above that high gain reflector array, at the bottom, you can see a bright green block. This block is our avionics bay, containing our primary command data and handle computer. The power system, and the attitude control system. And directly above it are a series of batteries.

Now, these batteries are your typical 8 or 6 series cell that you find in many flashlights these days. That you can find in many rechargeable electronics out there. MarCO as a whole, as I mentioned, is a technology demonstration mission. It's not required for InSight success. But, we do want to be able to provide that eight kilobit per second link along the way. Because this is a tech demo, we'll be starting to demonstrate technology as soon as we deploy off of the Atlas rocket that will be launching from Earth.

We'll be testing out the radio communications, proving that CubeSats can communicate with the deep space network. We'll show that we can maneuver with our propulsion system. And we'll calibrate ourselves to get ready for the Mars flyby taking place several months later. These are the first interplanetary CubeSats. As I mentioned, they're the first ones to go beyond low Earth orbit around the Earth.

And they were, not only small in size, but the team itself was quite small in building these. With only 10 to 20 active people on the team. With many other supporters, of course. They are the smallest spacecraft to ever independently fly to Mars.   They are separate from the InSight lander itself. And, primary built off low cost commercial off the shelf parts. Just some rough specifications, as I mentioned.

The volume is about the size of a cereal box and we do have two spacecraft. About 30 pounds each. And, the journey to Mars is going to take us about six and a half months.

One of the more entertaining pieces of our spacecraft is actually the primary computer that's on board. This little processor from Texas Instruments is often used in toasters, shower heads, and razor blades, actually. Yet, it is now controlling spacecraft headed out to Mars.

Now, the computing is not only concentrated in this one little chip, but is actually distributed around the spacecraft. But, the more complex items such as the radio or the attitude control system having their own onboard computers as well. The following slide 6 shows the back end of the space craft. The most prominent showing is the UHF antenna that sticks out the back. It also has to fold flat during launch.

But, it allows us to communicate with the InSight lander as it goes through EDL itself. To give you a better sense of what this looks like, if you go to the following slide, slide seven you can see the engineering model of the MarCO spacecraft. Some of the thermos blankets that we have on board and the radiators on the back side. This allowed us to actually do a fit check with the canister we'll be dispensing from.

And, along the bottom, you can see some of the actual flight hardware that's relative for scales for size just as the regular eight and a half by eleven paper on the left. The pen in front of the back row thrusters. Or the cube in the blue cannon technologies control system. And that cube is one centimeter in size. All of this technology relies on miniaturization to work. Continuing on to slide eight, you can actually see a picture of the flight model one spacecraft, after we did some of our final environmental testing.

The vibration testing to assure that we are ready for launch. Inside the space craft it is a very densely packed vehicle with all of our electronics just barely fitting in place. You can see much of the wiring. Some of the thermal blanketing on the inside of the spacecraft as well in the upper right there. While most spacecraft at JPL have a density of around .7 or .8 compared to water.

We are almost double that and packing twice as much in terms of electronics and mechanical items inside a spacecraft with density of around 1.4. Slide nine is really a family portrait. This shows on the right-hand side, the engineering model with the solar arrays fully deployed. In the middle, the second flight model with the top hatch open at this point. And on the right side is flight model one.

The first space craft you saw on the previous slide. At this point, both our flight spacecraft are almost ready to go and will be leaving JPL in the next few days as we get them ready to be attached to the launch vehicle. Slide 10 gives you a better perspective of what we're actually going to be doing at Mars. Following our six and a half month cruise, we're approximately 157 million kilometers away from Earth.

As InSight goes through its entry, decent, and landing sequence and passing through the Martian atmosphere. There will be a plasma trail that starts to erupt behind it. This plasma train interrupts communications. As well as provides quite a show of InSight as it's going down towards the service. After just initially passing in to the atmosphere and beginning to slow down, the InSight vehicle used a combination of rockets, parachutes, and other deployment mechanisms in order to safely land on the sequence.

And it's during this complex array of operations, that we'll be receiving data from the two MarCO spacecraft flying about 3,500 kilometers overhead. During it's relay operations, MarCO will be taking the data from InSight and then repackaging it ready for direct send to Earth to the deep space network. Specifically, 70 meter dish at Madrid during the sequence on here.

Providing the InSight team an indication of who well their vehicle is traveling through the atmosphere, just through the landing sequence itself. Over the next couple of months, there will be a lot of activity with the MarCO spacecraft as we prepare for launch along with the InSight.

I mentioned at the beginning that the launch window will open May 5th from Vandenberg Air Force Base. From the Atlas five. As we proceed throughout the atmosphere with InSight separate from, and independently fly to Mars, will be preceding with a number of firsts for small spacecraft, CubeSats included. As we go beyond Earth orbit, travel out to another planet, and demonstrate the capability of these small vehicles to support a larger mission.

This is absolutely a novel activity for JPL and one that we're that we're very excited about and we'll hope that you'll follow along with our mission all the way through November 26th when InSight goes through EDL. And begins its great journey as it continues to explore on the Martian surface. Thank you participating in this, today's discussion, and I would be, I would welcome any questions that you might have.

Heather Doyle: Wow, Dr. Klesh. That was amazing. I can't wait for this to actually happen and hope it all goes well. Does anybody out there want to unmute and ask Dr. Klesh any questions about what you just heard?

John Brandt: Yes. This is John Brandt in Albuquerque. You mentioned that this is a low-cost solution, or low-cost model. I'm interested if your engineers had used any sort of open source Arduino a Raspberry Pie components to add to this project.

Andy Klesh: Absolutely. In fact, every flight spacecraft has a ground interface that runs through an Arduinos on there. We use Arduinos and Raspberry Pies for many of our test activities. Especially if we're interfacing with a subsystem or sensor for a first time, as it's a low-cost opportunity for us to test various parts before we integrate them with more complex or more expensive pieces.

John Brandt: Excellent. Good luck.

Heather Doyle: And then, I heard Adrienne had a question?

Adrienne Provenzano: Yes. Hi this is Adrienne Provenzano, SSA. I had a couple of questions. One, I am wondering, do you have to do anything special to get small CubeSats to connect up with the deep space network? So, that's the first question.

Andy Klesh: Sure. And, we did have to do quite a few things to connect these CubeSats through DSN. First, and primarily, was develop an entirely new radio capable not only of communications but navigation away from Earth and utilizing the deep space network, which was a whole different series of protocols than most CubeSats are used to using.

We tested these radios at the DSNs test facility, and showed that we could both communicate and perform the navigation on here. And then, even now, we're starting to set up with various ground system tests that we can both connect with the InSight lander and pass its data back, as well as deconvolve all the data once it gets back down to the ground to interpret what's going on with our CubeSats and with InSight.

Adrienne Provenzano: That's great. So, I'm wondering is this data as it comes in, do you have plans to connect it with the Eyes On Universe program so that people can be able to visualize it in that way?

Andy Klesh: We're still working with both the media office and public outreach in terms of how we can connect various pieces and are open to any opportunities that might be suggested out there. I'm not sure that we've directly connected with Eyes On Universe, yet. But there are many discussions ongoing.

Adrienne Provenzano: That's great. And then, my last question, because I am sure there are other questions, are you aware of any other interplanetary CubeSat projects that are ongoing, on the board? Do you have any others you're working on yourself?

Andy Klesh: Absolutely. The INSPIRE project really brought forward the capability for cub sets to go beyond Earth. And here, MarCO's taking advantage of some of that technology. And, not only that, but NASA has invested in at least 13 missions that will be launching with SLS EM1, I believe, in 2019 now. Some of which are going out to the Moon. I believe there's four missions, at least, heading out to lunar orbit. There's near Earth asteroid scouts.

Which will actually use a solar sail to go fly by an asteroid. A number that are headed out around the sun. And then, innumerable more that are in the concept stage and are under current consideration for funding, traveling all over the solar system.

Adrienne Provenzano: That's great. And, are students involved in this project in any direct way at this point?

Andy Klesh: We do have students involved in several different ways. Several different students actually developed the hardware. Especially the command data handling board- our computer. And, the power system from the University of Michigan.

They then came out as interns throughout the process. We are looking to have students actually engaged in assisting with operations beginning this summer and we're working through that process now. As well as helping us test various radio capabilities throughout the mission operation itself.

Adrienne Provenzano: That's great. Thank you very much.

Heather Doyle: Any other questions out there?

Sarah Marcotte: This is Sarah. I have a question. Am I muted?

Heather Doyle: No. We can hear you, go ahead.

Sarah Marcotte: Good. Okay. I was like, uh-oh. Andy, I have a question about, so, what happens when MarCOs are flying past Mars. Do they get captured by Mars' gravity, or do they just keep going? After the EDL sequence and they, you know, radio their stuff. Are they going to go into orbit around Mars, or just fly by?

Andy Klesh: No. These spacecraft will actually fly by Mars and that's why we have to be so precise when they need to be there and where they need to be. They're traveling a too high of a velocity to actually be captured into orbit there.

Sarah Marcotte: Ah. Okay.

Andy Klesh: They are more strictly speaking, in the solar orbit and will continue around the sun.

Sarah Marcotte: Got it. Okay. And, my second question, you may have answered this and I apologize if you did. Why there are two. Instead of just one.

Andy Klesh: As these are low-cost space craft, we are traveling with redundancy here. Both will relay the same data from InSight. But, the do give us the opportunity to change where they are located and capture either the early phase of EDL and the latter phase. Or just be redundant during that entire period.

Sarah Marcotte: Oh, interesting. Okay. So, one might capture like a different set of telemetry than the other one, based on the other just may be a few seconds apart or something?

Andy Klesh: Exactly. And, we'll be able to tune that throughout operations based on performance of the spacecraft and where we deem the most mission critical data will be.

Sarah Marcotte: Got it. Thank you.

Man 1: Andy, I wondered if you could describe a little more information concerning the high gain antenna, please.

Andy Klesh: Sure. The high gain antenna is that checkered pattern dish, or plate that you might see on slide eight there at the back. Now, that is actually a passive antenna. What we call a high gain reflect array. The active part of it, the part that's actually broadcasting is that small little plate you see in the lower right of slide eight. Sticking up from the base of the spacecraft itself.

That antenna broadcasts out using eight small patch arrays, and it actually broadcasts a fairly broad beam. Now, when that beam hits the reflect array, all those patches are different sizes. They're actually different size copper pieces on there, that are printed on to that board.

And all those different sizes match a particular wave of that signal coming out. Changes the phase of the signal there, and that's what makes it a much more coherent, narrow beam as we send it back to Earth on there. Therefore, it's acting as somewhat of a parabolic disc to focus how we're getting that signal back down to the ground.

Chuck Schlemm: Hello, this is Chuck. I'd like to ask, during the seven minutes of entry, how much time, or what period of that will you be expecting to get a signal from InSight. Obviously after the initial interface but what, how many minutes of signal time do you expect to get? And, are there any other communications or experiments planned for the in-flight process? The six and a half months going to Mars. Thank you.

Andy Klesh: Our entire mission is, in essence, an experiment on here as every aspect of the vehicle is new, at least, for deep space and CubeSat framework. So, even looking at the data, seeing how systems reset or not in the deep space environment. How the thrusters perform over lifetime and such will all be experiments along the way.

But, we do also hope to have had in flight tests with a UHF signal coming from Earth to simulate InSight on the way out to Mars. Now, as for the actual time we'll be receiving and broadcasting, MarCO will be able to receive for around 20 to 25 minutes during the EDL process. InSight will start off with just a carrier tone. A single, signal. That will allow us to see that the spacecraft is there before they start broadcasting data. And, while we might lose data lock along the way.

In fact, it is expected based on the dynamics of the atmosphere on there, we will reacquire and continue to send data down. While the seven minutes of terror, as we say, is the most of the time that's spend in the atmosphere. InSight will be broadcasting a little bit longer than that, but well within out data budget to assure that we are able to get that data back to Earth.

Joe Komjathy: The SSA, Northern Michigan. Hey. I had a question with the size, the mere size of this CubeSat heading out with the attitude control system. What type of attitude control system is it using?

Andy Klesh: If you look at slide seven, you can actually see the majority of our attitude control system. MarCO relies on a few different things. For control, it has three reaction wheels held within that dark grey box in the lower right of that slide. These reaction wheels are primarily responsible for orienting the spacecraft. Whenever they spin out too quickly, or get saturated, we rely on the cold gas system to provide an opposing torque and allow us to spin those wheels back down. So, it is a very typical spacecraft.

At least compared to most larger ones in that we're relying on these reaction wheels in conjunction with the propulsion system there. But that is primarily what will orient us. Now, for determination of where we're actually pointed, we have both core sun sensors. Those are the small purple dots you see. Photodiodes as we call them.

That can figure out where the sun is in the sky. And onboard initial measurement unit with a gyro that is within that grey box. And a small telescope called a star tracker held just behind that red door that you see on the front there. And this will allow us to align with stars and determine how we are coordinated in the sky.

Joe Komjathy: Very good, thank you. Very competent CubeSat. Thank you.

Howard Andrews: Yes. I was just curious Dr. Klesh, if there's any plans. JPL has this history of building satellites with six-month, nine month, 10 month missions that last for five or 10 years. Is there any provisions for what kind of experimentations they might do when they're in solar orbit after they pass Mars?

Andy Klesh: This has been such a fast mission to put together that we have not allowed the team to think beyond that Mars point and entry, decent, and landing at this time. And approximately a week past that point, or a week to month after we broadcast that data back down to the earth, that will be the end of MarCO's primary mission. Along the way, depending on the performance of the spacecraft, we may then be able to consider other options, but for now, certainly, the primary mission will end just as we pass Mars.

Howard Andrews: Thank you.

Richard Pacheco: My question is on the primary processor to cost product and my question revolves around the hardening and protection of the item through space flight and how did you accomplish that?

Andy Klesh: We have used a majority of commercial parts throughout the spacecraft. And, so many of those parts are not hardened compared to the more traditional, larger vehicles here. So, what we tried to do is first intelligently choose what we were going to fly, with many of these parts having flown in low Earth orbit previously. Now, with commercial parts, you can't track that they are identical to previously flown or from the same lot and such. But, we did gain some confidence that similar parts have flown in low Earth orbit.

The second thing that we did was try to inquire to see what radiation testing had been done previously for those parts, again to build up our own content in our design choices. And then, third, as much as possible, we've tried to place parts behind as much shielding as we might be able to carry within this vehicle here. It does not protect against anything, but it does help is in terms of total ionizing dose and some of the radiation effects. And then, beyond radiation.

For all of these parts, we have put the spacecraft through a number of environmental tests including the traditional thermal vac, vibration testing, and other functional checks to make sure that this vehicle will be able to survive the rigors not only of launch, but of deep space travel. As a Cubesat mission, it does have inherently a high order of risk that we are having to go with this. And so, with that risk, we tried to design for failures along the way.

Rather than saying we will to assure that we never reset, we designed a processor so that it only takes about 14 milliseconds for the processor to reboot on here. And bring us back up, at least into a safe mode state. With all of these different aspects along the way, we hope to reduce the risk, but certainly, with all of the commercial parts, we are not a low risk mission.

Morgan Kempf: This is Morgan Kempf, Solar System Ambassador in Sasebo, Japan. I was, I'm just, very mesmerized by the whole MarCO mission. Everything from your speech to the details of the mission has just, without you saying the word, it has been efficient. The smallest processor on board that you're talking, the primary processor.

I missed the examples you gave in the power point has said that it's often been used in the toaster. Can you give me the other examples that you spoke, because I would like to incorporate that in one of my presentations that I'm planning to give for my Earth Day event. Because I find that this would be very, this would be great to use as, as I said, as an efficient, as going forward with JPLs space missions.

It's looking like your space missions are going in an efficient route, where satellites were these hunky items in the past and their just condensing more and more, just like cell phones were these huge walkie talkies, and now they're just these very flat items. Is that, going forward, can they get any smaller? Also. So, my first question being could you give me another example of where they primary processor is also used, and my second question being can they get any smaller than this? Thank you.

Andy Klesh: Sure. The other examples provided that we found, just from looking around online was that the processor is often found in shower heads and razor blades beyond toasters. You could say this is a brave little toaster going out to Mars. But, we are finding that the advancements in miniaturization in commercial technologies, be it in cell phones or automotive industry or other places in our lives.

Are providing useful technology that we can use in spacecraft to provide a more efficient platform. Ultimately, in space, we are constrained by how much mass we can actually launch into orbit or launch on our trajectory out to our destinations. The more efficient of design that we can find, and that is also rugged and easy to use, the better we can make these missions, the more capable we can make these missions.

And, it is, with every evolution, with every passing year, more technology is available to us, and we look to take advantage of this. And that's where CubeSats being able to demonstrate some of this commercial technology in deep space may provide significant benefits.

Janethsi Ostaiza-Cedeno: Hi. This is Janethsi from Puerto Rico. I'm curious as to how many satellites do we currently have orbiting Mars and what is the fastest communication link from those satellites?

Andy Klesh: Sarah I might have to ask you for the exact numbers there.

David Seidel: There are six in orbit. Three US, two European and one Indian.

Sarah Marcotte: Yes. I confess, I wouldn't be able to answer which is the, I don't know if you're asking me on fastest data rate, or it really depends on where the satellite is around Mars, right? …

Janethsi Ostaiza-Cedeno: Yes. It's about data rate.

Sarah Marcotte: Yes. We'll have to look that one up and get back to you.

David Seidel: Probably Mars Recognizant Orbiter. It's got the biggest antenna.

Sarah Marcotte: Yes. That one does have the biggest antenna.

Janethsi Ostaiza-Cedeno: All right. Thank you

Susan Morrison: I have a comment. This is Susan in Fresno. While we were talking about the dimensions of the mission and everything. I just happened to look down on something that I had copied. It's a NASA space place lesson called build your own satellite. And, that would be a really good lesson to use, if you wanted to discuss this particular mission. Because, the little satellites, the materials look very similar to those boxes you're talking about. So, just a suggestion. You could get that lesson off the Space Place website.

Heather Doyle: Yes. Any ambassadors out there, like Morgan was talking about her event that'd be a great suggestion. Some hands-on activity. And, side note. Thank you do David Seidel for his helping to answer those questions. That's who spoke up there. And answered some of the questions. But, any other questions for Dr. Klesh? All right. Well, if not, thank you so much for taking your time to explain this to us. It's really fascinating.

And, I think Kay can speak up, but I think this was the fastest telecon we ever had. You were so efficient even in your giving of the presentation. So, left plenty of time for questions. Thank you so much for being here. Our next telecon is actually going to be on February 22nd. In just a couple of days. And it's going to be a TESS mission overview with Dr. Schleider So, please join us then. It's going to be at 12pm pacific time. Thank you very much everyone for calling in, and also thank you Sarah for helping to set this up.

Sarah Marcotte: Yes. Thank you. I got a lot of my questions answered about MarCO. So, I'm thrilled.

Heather Doyle: Great. Have a great day everyone.

END